Apples originated in Central Asia. China is the world’s major apple producer, accounting for 39 million of the 86 million tons of apples produced in 2018, when the US produced five million tons of apples, Poland four million, Turkey 3.5 million, and Iran 2.5 million. Apples play an important role in mythology and religion as a forbidden fruit, as with Adam and Eve in the Garden of Eden.

Apples are the most consumed and the most valuable fruit produced in the US, worth about $3.6 billion a year. Americans had an average 45 pounds of apples available in 2018, including 17 pounds available to eat fresh and 22 pounds available as apple juice and other products. By comparison, Americans consume 28 pounds of fresh bananas a year and eight pounds each of fresh grapes, oranges, and avocados.

Rising US apple production and stable per capita consumption means that the US apple industry relies increasingly on exports of fresh apples; a quarter of US fresh apples are exported. Canada and Mexico are the largest markets for US fresh apples, but India and China are growing export markets. Trade tensions in 2020 reduced US apple exports to India and China after these countries raised tariffs on US apples. The US is a net importer of processed apple products such as apple juice, much of which is imported from China.

Apples can be stored and sold for a year or more after they are harvested. There was a record carryover stock of apples before harvesting began in 2020, which put downward pressure on apple prices. Retailers are advertising and selling apples by variety, and consumers have been willing to pay more for sweeter apples such as Cosmic Crisp and Honeycrisp.

**Structure**

Most US apples are from 800 to 1,000 farms, less than four percent of all apple farms. The Census of Agriculture reported 26,408 US apple farms in 2017, including 796 that each had 100 or more acres and collectively had 70 percent of US apple acreage, including 33 apple farms that had 1,000 or more acres and accounted for 20 percent of US apple acreage. Some 1,014 US apple farms had sales of at least $1 million, and they had two-thirds of total US apple acreage.

Over the past four decades, US apple acreage shrank by 29 percent, from 412,000 acres in 1980 to 291,000 acres in 2018, while apple tonnage rose 16 percent, from 4.4 million tons in 1980 to 5.1 million tons in 2018. Production increased as acreage shrank because yields rose by 65 percent to almost 18 tons an acre in high-density orchards with 1,200 to 1,400 dwarf trees that have limbs trained on trellis systems that make apple orchards appear like vineyards.

ERS data document a sharp drop in bearing US apple acreage, down from 434,000 acres in 2000 to 291,200 acres in 2018, including an 11 percent drop between 2017 and 2018. Washington is the leading US apple producer. The 2017 COA reported 2,522 apple farms and 179,000 acres of apples in the state, 47 percent of US apple acreage. New York was second with 13 percent of US apple acreage, followed by Michigan with 10 percent.
Between 2001 and 2017, Washington’s apple acreage declined eight percent amidst a replacement of traditional with new varieties. The top five varieties accounted for about 80 percent of Washington apple acreage in both 2001 and 2017, but Gala and Honeycrisp acreage rose while Red Delicious acreage fell by over half, and Gala replaced Red Delicious as the leading variety. Honeycrisp acreage was not measured in 2001, but accounted for 13 percent of acreage in 2017. Washington’s eight major apple varieties are Honeycrisp, Granny Smith, Cosmic Crisp, Red Delicious, Pink Lady, Gala, Fuji and Golden Delicious.

Growers are planting new varieties to get higher prices. Honeycrisp was worth three times more than Red Delicious in 2018-19, explaining why new plantings of Honeycrisp are surging while Red Delicious shrinks. Washington produced a record 142 million 40-pound boxes of apples in 2014, and 138 million boxes in 2019, giving the state’s apple growers revenues of about $3 billion a year.

### Labor

Hand workers prune and train tree limbs and thin and harvest apples. There are four major hand labor tasks: (1) pruning and training trees at a cost of $940 or 50 hours an acre for Gala apples, (2) thinning fruit at a cost of $1,033 or 54 hours an acre, (3) protecting apples from sunburn with netting at a labor cost of $1,200 or 63 hours per acre, and (4) harvesting apples at a cost of $2,390 or 126 hours an acre, plus an additional $680 or 36 hours an acre to supervise harvest workers, check picked apples, and transport full bins to packing houses.

Harvesting is the most expensive of these four steps, but accounts for only a third of the $6,000 of labor costs per acre to produce apples. Workers climb tripod ladders that lean into trees and pick from top to bottom into bags or buckets that hang over their shoulders. Full bags are dumped into 900- to 1,000-pound bins that hold 22 bushels.

Working from ladders in orchards on uneven ground can be dangerous, and most apple pickers are young men able to pick apples quickly from trees that are 15 to 20 feet high, earning $20 to $30 per bin and over $20 an hour. Up to a third of a picker’s time is spent moving and positioning ladders rather than picking.

Washington requires almost all farms to participate in unemployment insurance, and the QCEW reported that 740 apple orchard establishments (NAICS 111331) hired an average 22,200 workers and paid them $638 million in wages in 2019. Apple establishments had over 30,000 workers employed in July and less than 15,000 in February.

Average employment in QCEW data represents employees on the payroll for the period that includes the 12th of the month, summed and divided by 12, and misses workers who were hired only in other weeks of the month. The state’s apple industry estimates that at least 50,000 workers harvest apples each year, including 20,000 H-2A workers.

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<td>25,500</td>
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<td>23%</td>
<td>61%</td>
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<td>Honeycrisp</td>
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<td></td>
<td></td>
<td>$53</td>
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<td>Granny Smith</td>
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<td>$29</td>
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<td>100%</td>
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<td>Top 5 share</td>
<td>78%</td>
<td>83%</td>
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**Price is for a 40-pound carton of apples**
Only a third of the WA apple farms identified in the COA are enrolled in the state’s UI system. This could reflect ownership structures, as when absentee owners rely on other apple growers, labor contractors, or farm management services to harvest their apples.

**Alternatives**

There are three major options to reduce the cost of harvesting apples: pick by hand and improve worker productivity with mechanical aids, adapt shake and catch machines to harvest apples in once-over fashion, or develop robotic arms to harvest individual apples in multiple passes through the orchard. Each harvesting system functions best with dwarf trees and limbs trained to produce fruit in trellises or with a Y-architecture.

The first option is to replace ladders with mechanical aids such as platforms that carry harvest workers and the bins into which workers dump full bags of apples. Platform crews of eight often involve four workers on the platform, two on each side of the platform who pick from the ground, and two behind the machine who also pick from the ground. Platforms, which cost about $65,000, are raised and lowered hydraulically, and workers normally share the piece rate wage that reflects the number of bins picked by the crew.

There are two types of mechanical harvesters: shake and catch and selective. Shake-and-catch machines are already used to pick peaches and plums that are processed and dried, and can pick fast because they make one pass through the orchard and harvest all of the fruit. Machines grip the trunk and deliver a jolt that dislodges the apples into a catching frame that transfers the harvested fruit into bins that are transported to packing plants, where electronic eyes and humans select the marketable fruit. Shake-and-catch technologies are mature and are sometimes used to harvest processing and low-value fresh apples, but have the disadvantage of harvesting immature as well as mature fruit and damaging some harvested fruit.

Selective harvesters imitate humans by finding and picking individual apples, thus increasing the amount of marketable fruit from an orchard. Selective picking machines seek the optimal combination of speed and accurate recognition of ripe fruit, and use artificial intelligence and LIDAR (light detection and ranging) to find ripe apples.

Selective pickers have arms with grasping hands to remove individual apples and place them on a conveyor belt for transport to a bin carried by the machine. The machine’s cameras and software based on algorithms similar to those used in facial recognition learns over time to pick faster, but remains slower than humans.
The apple mechanization challenge highlights the trade-offs inherent in developing labor-saving technologies for fresh fruits and vegetables. Harvesting platforms make picking easier but require sharing piece rate wages among a crew, which some workers reject. Shake-and-catch machines work best on lower value varieties that are planted and trained for mechanical harvesting, but there are few new plantings of Red and Golden Delicious and thus few opportunities to use shake-and-catch machines on the varieties for which they are best suited. New plantings of high-value varieties such as Honeycrisp generate high grower revenues, making growers reluctant to use machines that miss or damage valuable fruit and encouraging them to continue to hand harvest.

Over the next decade, a rising share of fresh apples are likely to be harvested by US and H-2A workers using platforms that increase worker productivity. Improving detection and grasping technologies and the falling cost of electronics should speed development of selective harvesters, which are likely to evolve faster than biological advances that could promote the uniform ripening of high-value apple varieties to facilitate shake-and-catch harvesting into padded catching frames.

Labor costs rather than trade are the major driver of apple mechanization. The US is a net exporter of fresh apples and an importer of apple products. Since apples can be stored under controlled atmosphere conditions that use high concentrations of carbon dioxide and air filtration to delay ethylene-induced ripening, they are less perishable than many other fresh fruits and vegetables. US growers have a comparative advantage due to their access to proprietary varieties that are favored by consumers and cannot be planted elsewhere.

Shake and Catch Apple Harvester

Selecting Apple Harvester

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